

TABLE 1 OF § 1065.303—SUMMARY OF REQUIRED CALIBRATION AND VERIFICATIONS—Continued

Type of calibration or verification	Minimum frequency <sup>1</sup>
§ 1065.378: NO <sub>2</sub> -to-NO converter conversion .....	Upon initial installation, within 35 days before testing, and after major maintenance.
§ 1065.390: PM balance and weighing .....	Independent verification: upon initial installation, within 370 days before testing, and after major maintenance. Zero, span, and reference sample verifications: within 12 hours of weighing, and after major maintenance.
§ 1065.395: Inertial PM balance and weighing .....	Independent verification: upon initial installation, within 370 days before testing, and after major maintenance. Other verifications: upon initial installation and after major maintenance.

<sup>1</sup> Perform calibrations and verifications more frequently than we specify, according to measurement system manufacturer instructions and good engineering judgment.

<sup>2</sup> Perform linearity verification either for electrical power or for current and voltage.

<sup>3</sup> The CVS verification described in § 1065.341 is not required for systems that agree within  $\pm 2\%$  based on a chemical balance of carbon or oxygen of the intake air, fuel, and diluted exhaust.

[79 FR 23762, Apr. 28, 2014]

#### § 1065.305 Verifications for accuracy, repeatability, and noise.

(a) This section describes how to determine the accuracy, repeatability, and noise of an instrument. Table 1 of § 1065.205 specifies recommended values for individual instruments.

(b) We do not require you to verify instrument accuracy, repeatability, or noise.

However, it may be useful to consider these verifications to define a specification for a new instrument, to verify the performance of a new instrument upon delivery, or to troubleshoot an existing instrument.

(c) In this section we use the letter “y” to denote a generic measured quantity, the superscript over-bar to denote an arithmetic mean (such as  $\bar{y}$ ), and the subscript “<sub>ref</sub>” to denote the reference quantity being measured.

(d) Conduct these verifications as follows:

(1) Prepare an instrument so it operates at its specified temperatures, pressures, and flows. Perform any instrument linearization or calibration procedures prescribed by the instrument manufacturer.

(2) Zero the instrument as you would before an emission test by introducing a zero signal. Depending on the instrument, this may be a zero-concentration gas, a reference signal, a set of reference thermodynamic conditions, or some combination of these. For gas analyzers, use a zero gas that meets the specifications of § 1065.750.

(3) Span the instrument as you would before an emission test by introducing

a span signal. Depending on the instrument, this may be a span-concentration gas, a reference signal, a set of reference thermodynamic conditions, or some combination of these. For gas analyzers, use a span gas that meets the specifications of § 1065.750.

(4) Use the instrument to quantify a NIST-traceable reference quantity,  $y_{ref}$ . For gas analyzers the reference gas must meet the specifications of § 1065.750. Select a reference quantity near the mean value expected during testing. For all gas analyzers, use a quantity near the flow-weighted mean concentration expected at the standard or expected during testing, whichever is greater. For noise verification, use the same zero gas from paragraph (d)(2) of this section as the reference quantity. In all cases, allow time for the instrument to stabilize while it measures the reference quantity. Stabilization time may include time to purge an instrument and time to account for its response.

(5) Sample and record values for 30 seconds (you may select a longer sampling period if the recording update frequency is less than 0.5 Hz), record the arithmetic mean,  $\bar{y}_i$  and record the standard deviation,  $\sigma_i$  of the recorded values. Refer to § 1065.602 for an example of calculating arithmetic mean and standard deviation.

(6) Also, if the reference quantity is not absolutely constant, which might be the case with a reference flow, sample and record values of  $y_{ref}$  for 30 seconds and record the arithmetic mean of the values,  $\bar{y}_{ref}$ . Refer to § 1065.602 for an

example of calculating arithmetic mean.

(7) Subtract the reference value,  $y_{ref}$  (or  $\bar{y}_{ref}$ ), from the arithmetic mean,  $\bar{y}_i$ . Record this value as the error,  $\epsilon_i$ .

(8) Repeat the steps specified in paragraphs (d)(2) through (7) of this section until you have ten arithmetic means ( $\bar{y}_1, \bar{y}_2, \bar{y}_i, \dots, \bar{y}_{10}$ ), ten standard deviations, ( $\sigma_1, \sigma_2, \sigma_i, \dots, \sigma_{10}$ ), and ten errors ( $\epsilon_1, \epsilon_2, \epsilon_i, \dots, \epsilon_{10}$ ).

(9) Use the following values to quantify your measurements:

(i) *Accuracy*. Instrument accuracy is the absolute difference between the reference quantity,  $y_{ref}$  (or  $\bar{y}_{ref}$ ), and the arithmetic mean of the ten  $\bar{y}_i, \bar{y}$  values. Refer to the example of an accuracy calculation in §1065.602. We recommend that instrument accuracy be within the specifications in Table 1 of §1065.205.

(ii) *Repeatability*. Repeatability is two times the standard deviation of the ten errors (that is, repeatability =  $2 \cdot \sigma\epsilon$ ). Refer to the example of a standard-deviation calculation in §1065.602. We recommend that instrument repeatability be within the specifications in Table 1 of §1065.205.

(iii) *Noise*. Noise is two times the root-mean-square of the ten standard deviations (that is, noise =  $2 \cdot rms_\sigma$ ) when the reference signal is a zero-quantity signal. Refer to the example of a root-mean-square calculation in §1065.602. We recommend that instrument noise be within the specifications in Table 1 of §1065.205.

(10) You may use a measurement instrument that does not meet the accuracy, repeatability, or noise specifications in Table 1 of §1065.205, as long as you meet the following criteria:

(i) Your measurement systems meet all the other required calibration, verification, and validation specifications that apply as specified in the regulations.

(ii) The measurement deficiency does not adversely affect your ability to demonstrate compliance with the applicable standards.

[70 FR 40516, July 13, 2005, as amended at 73 FR 37301, June 30, 2008; 75 FR 23037, Apr. 30, 2010; 79 FR 23763, Apr. 28, 2014]

#### § 1065.307 Linearity verification.

(a) *Scope and frequency*. Perform linearity verification on each measurement system listed in Table 1 of this section at least as frequently as indicated in Table 1 of §1065.303, consistent with measurement system manufacturer's recommendations and good engineering judgment. The intent of linearity verification is to determine that a measurement system responds accurately and proportionally over the measurement range of interest. Linearity verification generally consists of introducing a series of at least 10 reference values to a measurement system. The measurement system quantifies each reference value. The measured values are then collectively compared to the reference values by using a least-squares linear regression and the linearity criteria specified in Table 1 of this section.

(b) *Performance requirements*. If a measurement system does not meet the applicable linearity criteria referenced in Table 1 of this section, correct the deficiency by re-calibrating, servicing, or replacing components as needed. Repeat the linearity verification after correcting the deficiency to ensure that the measurement system meets the linearity criteria. Before you may use a measurement system that does not meet linearity criteria, you must demonstrate to us that the deficiency does not adversely affect your ability to demonstrate compliance with the applicable standards.

(c) *Procedure*. Use the following linearity verification protocol, or use good engineering judgment to develop a different protocol that satisfies the intent of this section, as described in paragraph (a) of this section:

(1) In this paragraph (c), the letter “y” denotes a generic measured quantity, the superscript over-bar denotes an arithmetic mean (such as  $\bar{y}$ ), and the subscript “<sub>ref</sub>” denotes the known or reference quantity being measured.

(2) Use good engineering judgment to operate a measurement system at normal operating conditions. This may include any specified adjustment or periodic calibration of the measurement system.

(3) If applicable, zero the instrument as you would before an emission test